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LIMITED CIRCULATION

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AGRICULTURAL MEMORANDUM NO. 987

A DROUGHTINESS FACTOR FOR AGRICULTURAL LAND CLASSIFICATION

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Summary

A Scheme is described which enables the droughtiness of the land in any location in England and Wales to be determined from rainfall and temperature climate maps used in conjunction with an assessment, or a locally measured, available water content of the soil. This Scheme for assessing drought is designed not to be specific to a particular growing season and therefore is not crop specific.

1. Introduction

The median value (1961-80) of the end of month Potential Soil Moisture Deficits (PSMD) which occur each year have been recommended for the assessment of agricultural drought, Thomasson (1979). The deficit represents an accumulation of the balance between rainfall and evapotranspiration, calculated on the daily basis, which when combined with the Available Water Content (AWC) of the soil and the transpiration characteristics of the crop can be used to assess the droughtiness of a specific crop. This method can be generalised so that it is applicable to a broad range of crops, rather than individual crops, by considering grass which has a full crop cover throughout the drought season and using the median value of the annual maximum PSMD (MPSMD) in place of the crop specific end of month PSMD. The main difficulty with these methods for assessing agricultural droughtiness is the shortage of good meteorological data for determining long period averages of PSMD. Data does exist but neither the data or the derived maps are accurate enough for statutory purposes as envisaged for agricultural land classification (ALC).

It is necessary to understand why the existing data is not adequate and hence develop an alternative Scheme which is scientifically sound and reliable for assessing the geographical variations of the meteorological factors contributing to agricultural drought.

2. The Climate Data

The most advanced numerical model for computing PSMD on a routine operational basis in the UK is the Met Office Rainfall and Evaporation Calculation System (MORECS), Thompson et al (1981). The PSMD calculations use daily rainfall and daily averages of air temperature, sunshine, vapour pressure and wind speed as input weather variables. If the daily data is used for 20 years, 1961-80, then average end of month or average annual maximum PSMD may be calculated. The difficulties are caused by too few stations measuring all the weather variables all of the time, and site differences.

There are 94 stations which continuously measure daily rainfall and daily maximum and minimum temperatures during the years 1961-80, see Table 1, but only 20 of these stations, eg. airfield met office stations, provide an average daily vapour pressure deficit. For the MORECS calculation of MPSMD the once-a-day observation, invariably 09.00 GMT, of dry bulb and wet bulb temperature were used to derive an 09.00 GMT vapour pressure deficit. This was assumed to be equal to the average daily vapour pressure deficit. The assumption is good for many stations but the sensitivity of MORECS PSMD calculations to errors in vapour pressure deficit causes some large discrepancies. The lack of good wind observations at many of the sites also significantly contributed to the data problem, eg Stations 2, 54, 56, 59, 77, in Table 1 and Figs 1 and 2

From the above it appears that the best chance of modelling agricultural drought

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depends upon the numerous observations of rainfall and temperature which are both related to topographic height in a well defined way. Few stations continuously measured sunshine hours in the years 1961-80 and earlier.

The relationship between sunshine and topographic height is not so well defined and for drought purposes the variation is summer temperature may be assumed to represent the geographical variation of Sunshine hours.

3. The Summer Average Rainfall

There are several thousand stations in England and Wales making daily measurements of rainfall and these data have been analysed using a topographic map as a background field to produce a detailed map of Annual Average Rainfall (AAR) and Summer Average Rainfall (SAR) 1941-70. The Met Office have produced both these maps on a scale of 1:625,000. The SAR is ideally suited to represent the average input of moisture to the soil during the period April-September. There are no plans to update the period to 1951-80 or 1961-80. A schematic map of SAR (1941-70) is presented in Fig.3.

4. Summer Temperature

The evaporation and transpiration from the soil and plant surface is governed by complex interactions between the soil moisture status, soil type, crop type, ground cover, temperature, sunshine, humidity and wind speed. For a crop such as grass and any specified soil the meteorological variability is largely described by the variability of the temperature plus an exposure to wind factor which may be site specific like soil characteristics are. The dominance of the air temperature is fortunate because after rainfall temperature is the next most observed weather parameter and as well as the 94 stations continuously measuring daily maximum and minimum temperatures during 1961-80 there are another 140 stations with temperature records for part of this period.

The average daily summer temperatures can be derived by halving the sum of the maximum and minimum temperatures. A summer temperature can be obtained by averaging the individual average daily temperatures for the period April-September or the average daily temperatures can be accumulated in the same way as they are in the T-SUM calculations. The latter has the advantage of expanding the scale of the differences between stations. The average summer temperature or the summer accumulated temperature is obtained from the values of the individual 20 years. In practice the median rather than the average accumulated temperature is used and a schematic map is presented in Fig.4.

5. A Physical - Empirical MPSMD Model

Assuming MPSMD is a good parameter for assessing the geographical variations of agricultural droughtiness for a broad range of crops then it only remains to map this parameter. Unfortunately the mapping task is restricted by too few stations measuring all the weather factors necessary to derive PSMD. An indirect method of mapping is possible, however, by relating MPSMD to only a few of the most dominant weather factors, ie summer rainfall and summer accumulated temperature, both of which may be mapped with relative accuracy and both are related to altitude in a well defined way.

In practice the air temperature closely relates to the hours of sunshine and the vapour pressure deficit, and to a lesser extent the wind speed. Therefore the air temperature (evaporative factor) and rainfall (moisture input factor) were used to model the medium value of the annual maximum PSMD using the data from the best of the PSMD stations to determine the model regression equation. The median value of PSMD was used rather than the average value because with only 20 years of annual maxima values available the median is not affected by a few extremes which are not representative of the 20 year sample.

The annual maximum PSMD typically occurs during the July, August or September months and it is the summer temperature and the summer rainfall which are important.

The total stations available for directly computing the median value of MPSMD for the years 1961-80 are listed in Table 1. Most of these stations only make one weather observation a day and this can be shown to give variable accuracy because the assumption is made that the 09.00 GMT vapour pressure deficit is equal to the 24 hour average value. Therefore the modelling of MPSMD should be biased by data from the 24 hour Met Office stations which only total 20 in number.

A multiple linear regression analysis was used of the form:

$$MPSMD = A_0 + A_1 T_S + A_2 R_S \quad \text{- - - -

Typically the AWC varies from less than 100 mm in the light soils to greater than 150 mm in heavy soils. Unlike climate which can only be assessed from long period records, the AWC can be determined by on-site measurements whenever the need arises. In practice this is easier said than done because of the small scale natural variability of the AWC and the inherent sampling problems.

7. Agricultural Droughtiness Factor

If accumulated summer temperature is plotted against average summer rainfall plus AWC then a droughtiness index can be derived as illustrated in Fig.9. The lines of demarkation for droughtiness must be refined by experimental evidence using soil samples from different climatic areas of the country. This has yet to be done.

The demarkation lines shown in Fig.9 are based on some data derived by Jones (Soil Survey) for soils with AWC equal to 150 mm, private communication.

Any comments or suggestions relating to this paper should be addressed to the author.

REFERENCES

Thomasson A J (1979). Soil droughtiness in Soil Survey Applications Tech.Mono., No. 13. Harpenden : Soil Survey of England and Wales

Thompson N, Barrie I, and Ayles M (1981) Meteorological Office Rainfall and Evaporation Calculation System: MORECS - Hydrological Memorandum No 45 - Met. Office Publication.

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Wolverhampton

19 June 1984

TABLE 1- STATION DATA FOR MODELLING MAX PSMD (*) AND FOR COMPARISON MAX PSMD DERIVED FROM MORECS USING DAILY METEOROLOGICAL DATA.

		H (m)	Ts Apr - Sept	Rs Apr - Sept	PSMD Morecs	PSMD *
1	ASKAM BRYAN	34	2300	322	147	159
2	AYLESBURY	96	2417	312	131	185
3	BOSCOMBE	126	2404	326	192	176
4	BRANHAM	54	2231	335	129	142
5	BUDE	15	2398	375	139	154
6	CARDINGTON	29	2376	278	189	190
7	CAMBRIDGE (BOT)	12	2496	291	211	210
8	CAMBRIDGE (NIAB)	26	2467	295	227	202
9	CAWOOD	6	2286	307	141	161
10	CHELTENHAM	65	2509	339	161	188
11	COCKLE PARK	99	2055	368	103	110
12	COLTISHALL	17	2383	302	183	182
13	CRANWELL	62	2340	311	168	170
14	DURHAM	102	2161	327	123	133
15	EASTBOURNE	7	2546	344	175	191
16	EAST MALLING	37	2450	318	183	188
17	ELMDON	96	2318	342	171	155
18	EVERTON	16	2472	341	172	181
19	FAVERSHAM	48	2426	316	196	184
20	FERNHURST	57	2396	396	147	145
21	FILTON	59	2473	382	175	161
22	FINNINGLEY	10	2423	303	190	190
23	GATWICK	59	2415	354	139	166
24	GLOUCESTER	23	2558	322	198	206
25	GORLESTON	4	2410	283	206	196
26	GOUDHURST	85	2392	369	151	156
27	HASTINGS	45	2521	317	175	202
28	HAYDON BRIDGE	79	2148	370	136	123
29	HEATHROW	25	2610	313	233	221
30	HIGH MOWTHORPE	175	2106	374	122	116
31	HODDESDON	43	2517	321	187	247
32	HULL	2	2437	328	184	181
33	HURLEY	43	2425	340	162	173
34	HURN	10	2447	345	165	175
35	KEW	6	2615	293	232	234
36	LEEMING	32	2257	292	153	160
37	LONG SUTTON	145	2371	298	150	181
38	LOWESTOFT	25	2411	285	199	195
39	LYNEHAM	145	2353	345	172	160
40	MANSTON	44	2473	270	252	216
41	MARTYR WORTHY	84	2395	366	152	158
42	NEWPORT	64	2288	344	132	150
43	NEWTON RIGG	171	2107	400	111	113
44	OXFORD	63	2516	322	184	198
45	PERSHORE	40	2480	331	187	187
46	PORTON	111	2347	342	155	160
47	PRESTON WYNNE	84	2311	328	141	168
48	ROTHAMSTEAD	128	2348	343	155	160
49	RUSSINGTON	3	2437	324	167	183
50	SANTON DOWNHAM	24	2326	336	142	159
51	SHAWBURY	72	2300	346	147	151
52	SHOEBURYNESS	2	2548	264	249	237

		H	Ts	Rs	PSMD	PSMD
		(m)	Apr - Sept	Apr - Sept	Morecs	*
53	SILSOE	61	2371	278	174	189
54	SKEGNESS	5	2371	306	131	178
55	STANSTEAD	101	2397	312	174	181
56	STARCROSS	9	2434	348	197	171
57	STRATFORD	49	2378	325	157	172
58	SUTTON BONINGTON	48	2344	299	191	175
59	TERRINGTON	3	2394	300	151	185
60	VALLEY	10	2345	392	165	141
61	WARSOP	46	2250	308	155	154
62	WATTISHAM	89	2391	293	205	188
63	WELLESBOURNE	47	2380	310	161	178
64	WISLEY	35	2472	316	172	193
65	WITTERING	73	2386	306	196	181
66	WOBURN	89	2341	318	152	168
67	WRITTLE	32	2433	284	191	200
68	WYE	56	2434	330	166	180
69	WYTON	40	2469	292	216	204
70	YEOVILTON	18	2389	354	144	162
71	ABERPORTH	133	2245	417	134	123
72	BRADFORD	134	2234	404	125	125
73	BUXTON	307	2033	588	82	87
74	CARLISLE	26	2249	459	114	112
75	CRUMBLAND	245	2239	474	126	107
76	CWMYSTWYTH	301	1991	758	49	62
77	DALE FORT	33	2404	419	198	136
78	GOGERDDAN	31	2314	467	91	112
79	HAWKRIDGE	314	2088	651	82	77
80	HELMSHORE	260	2080	711	63	69
81	KEELE	179	2223	408	119	123
82	KIRKHAM	24	2266	473	124	108
83	LOGGERHEADS	210	2074	423	110	107
84	LONG ASHTON	45	2462	428	174	137
85	LYONSHALL	155	2314	411	151	131
86	MOUNT BATTEN	27	2456	422	151	139
87	PEN-Y-FFRIDD	84	2323	503	96	100
88	RHOOSE	67	2387	445	133	124
89	RINGWAY	75	2382	417	139	135
90	ROSEWARNE	76	2377	421	114	133
91	SILPHO MOOR	203	2049	421	107	105
92	SLAIDBURN	192	2077	698	69	70
93	SWANSEA	10	2534	520	103	100
94	TRAWSGOED	61	2269	515	78	96

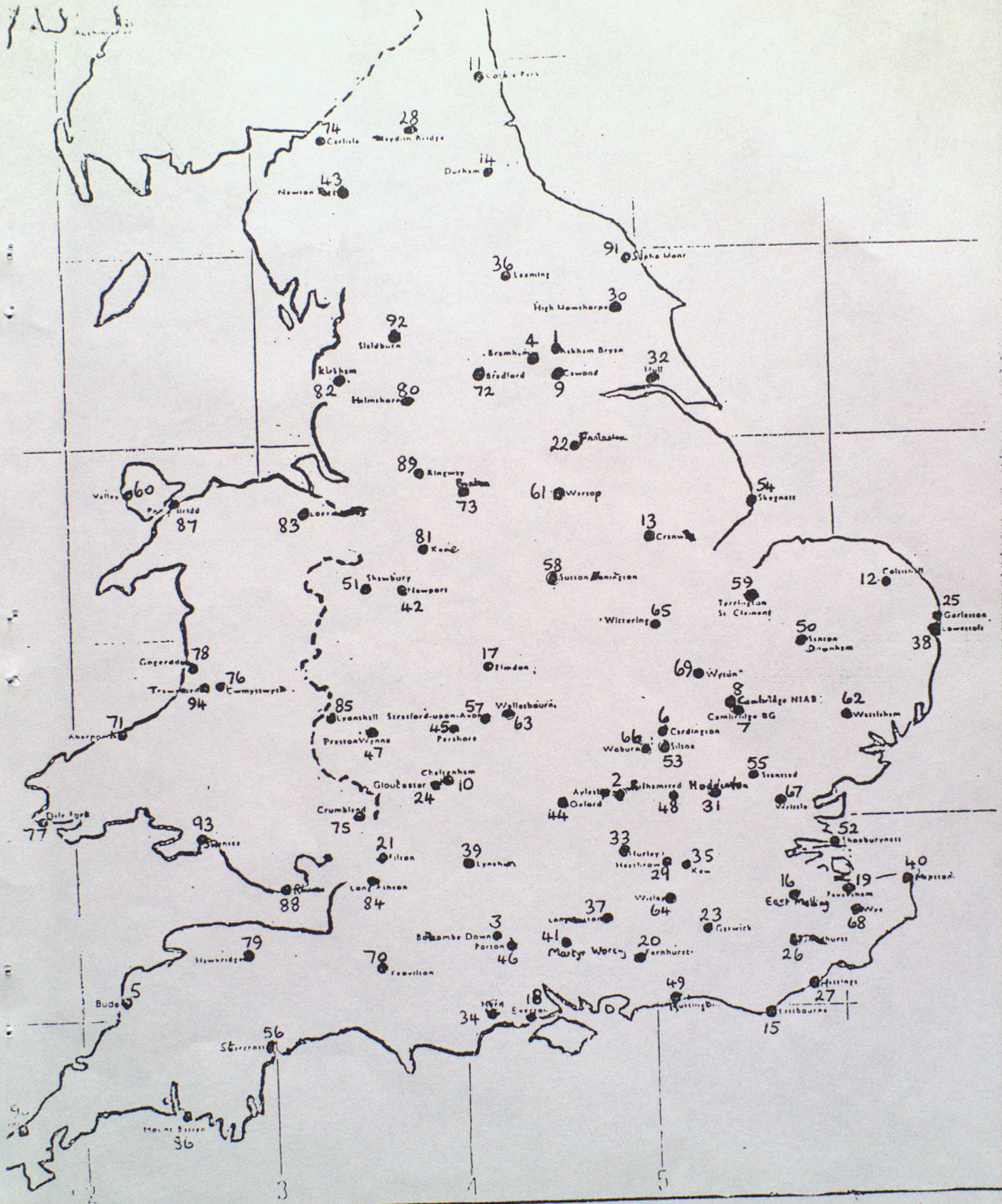


FIG 1 STATION LOCATION AND NUMBERS CORRESPONDING TO TABLE 1 FOR MORECS MAX PSMD CALCULATIONS.

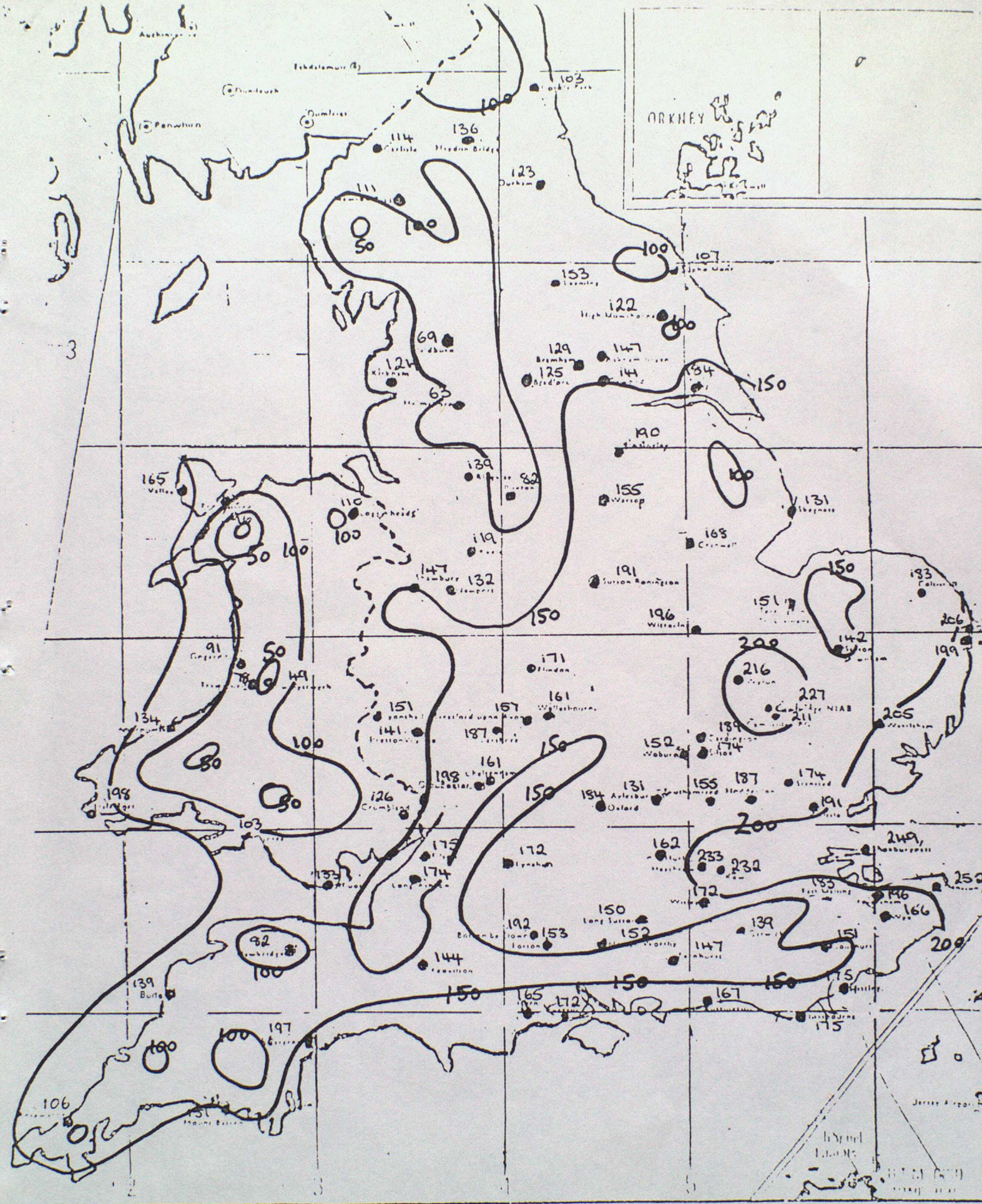


Fig 2 Median value of Annual Maxima of PSMD (1961-80)

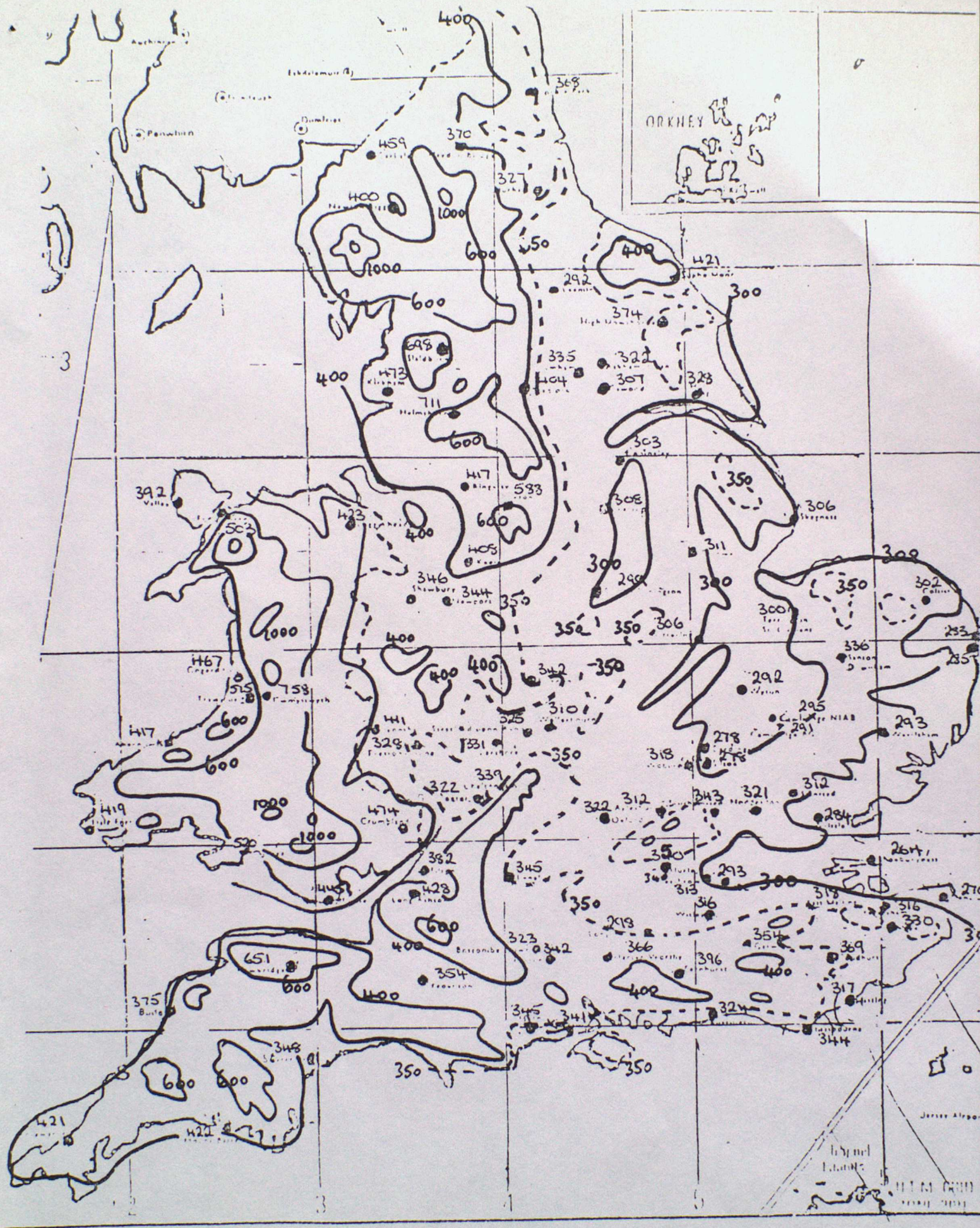


Fig 3. Summer Average Rainfall. (1941-70) — April to Sept.

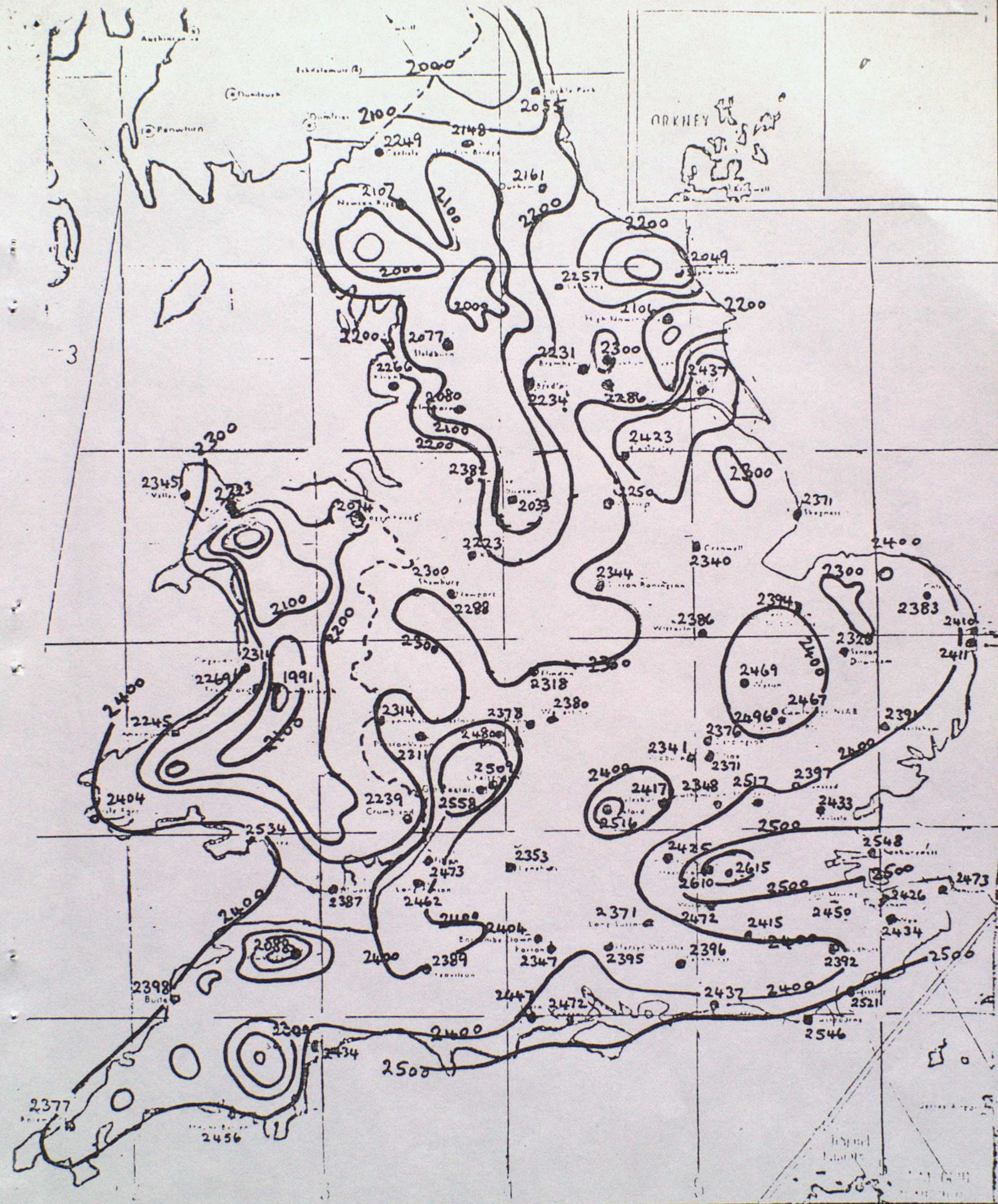


Fig 4 Median Value of Accumulated Temperature (April - Sept) above 0°C

Station Numbers Plotted correspond to Numbers in Table I

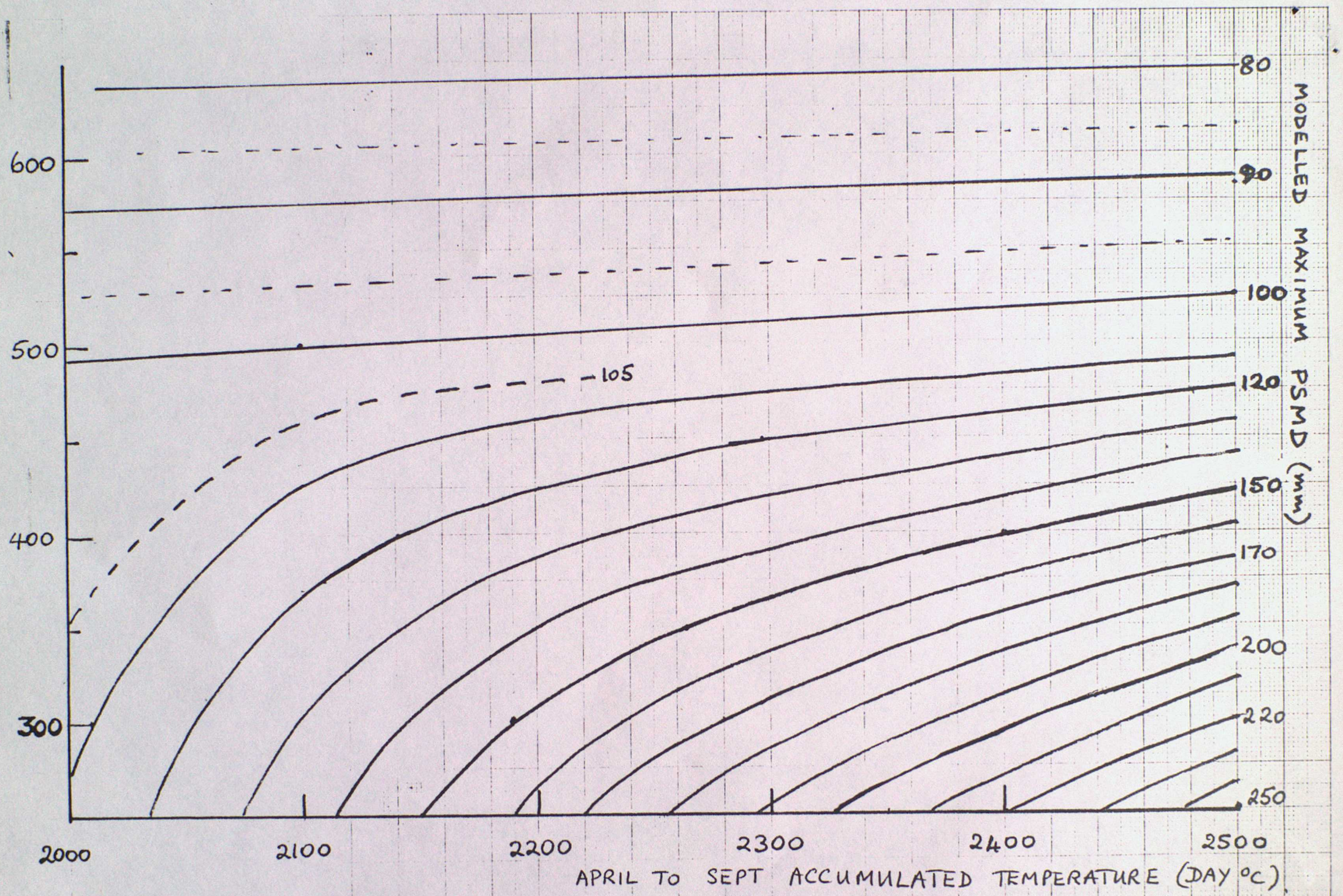
Summer Rainfall (mm).

700
600
500
400
300
200

0
50
100
150
200
250
300

MAX PSMD (mm)

FIG 8 SUMMER AVERAGE RAINFALL VERSUS MORECS MEDIAN VALUE OF MAXIMUM PSMD



GURE A. MAX PSMD MODELLED ON SUMMER RAINFALL AND ACCUMULATED TEMPERATURE.

MAXIMUM POTENTIAL SMD (mm)

200
150
100
50
0

300
400
Summer Rainfall (mm)
500
600
700
800
900

2000 2100 2200 2300 2400 2500 2600

APRIL – SEPT ACCUMULATED TEMPERATURE (DAY °C)

FIG. 7 MODELLED RELATIONSHIP BETWEEN MAX PSMD, ACCUMULATED TEMPERATURE AND RAINFALL

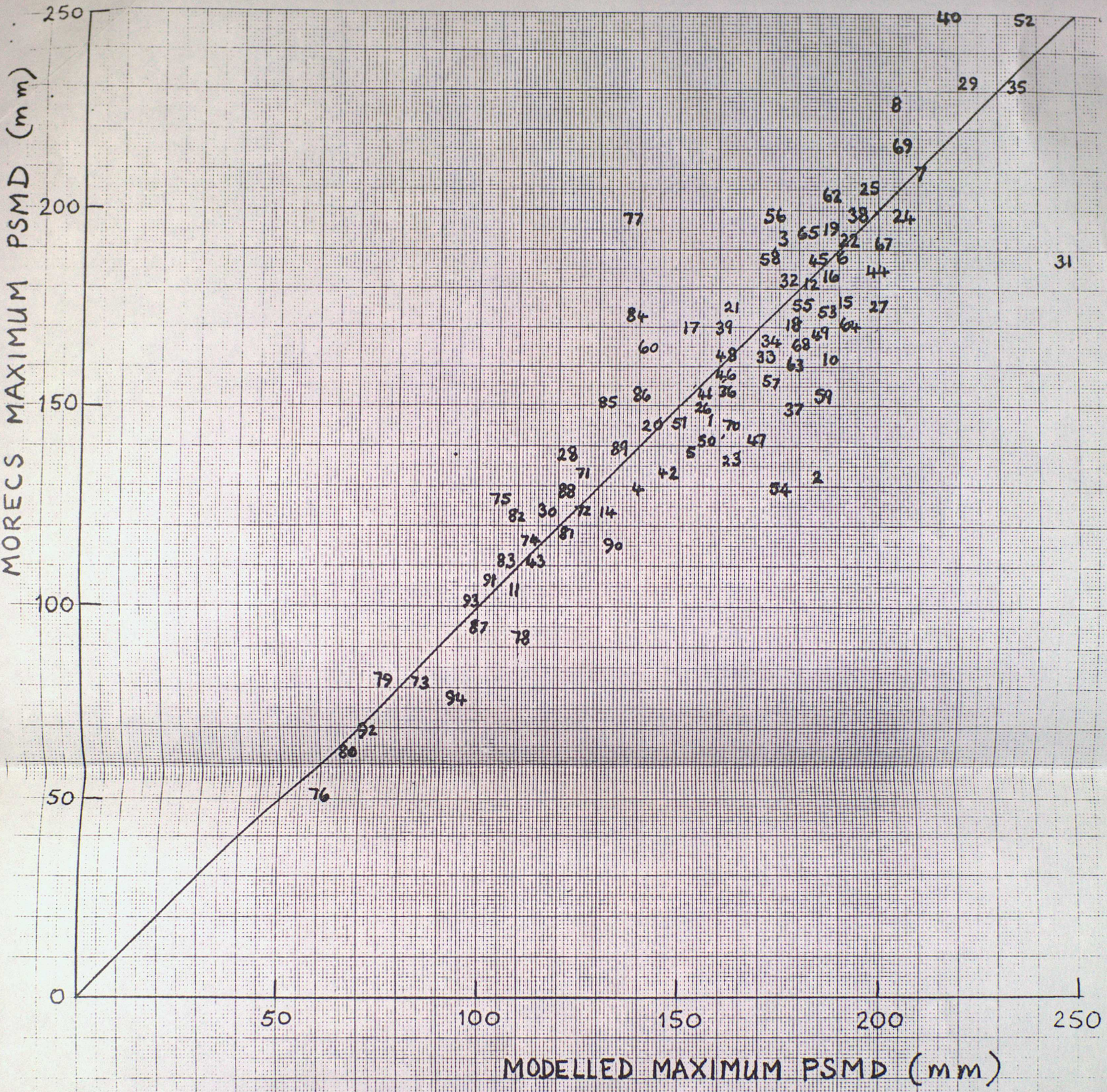


FIG 8 COMPARISON OF MEDIAN VALUES OF ANNUAL MAXIMUM PSMD DERIVED FROM MORECS (USING DAILY MET INPUT) AND VALUES FROM AN EMPIRICAL MODEL USING SUMMER AVERAGE RAINFALL, R_S, (1941-70) AND MEDIAN SUMMER ACCUMULATED TEMPERATURE, T_S, (1961-80).

Plotted Numbers correspond to Station Numbers in TABLE 1.

Day °C.

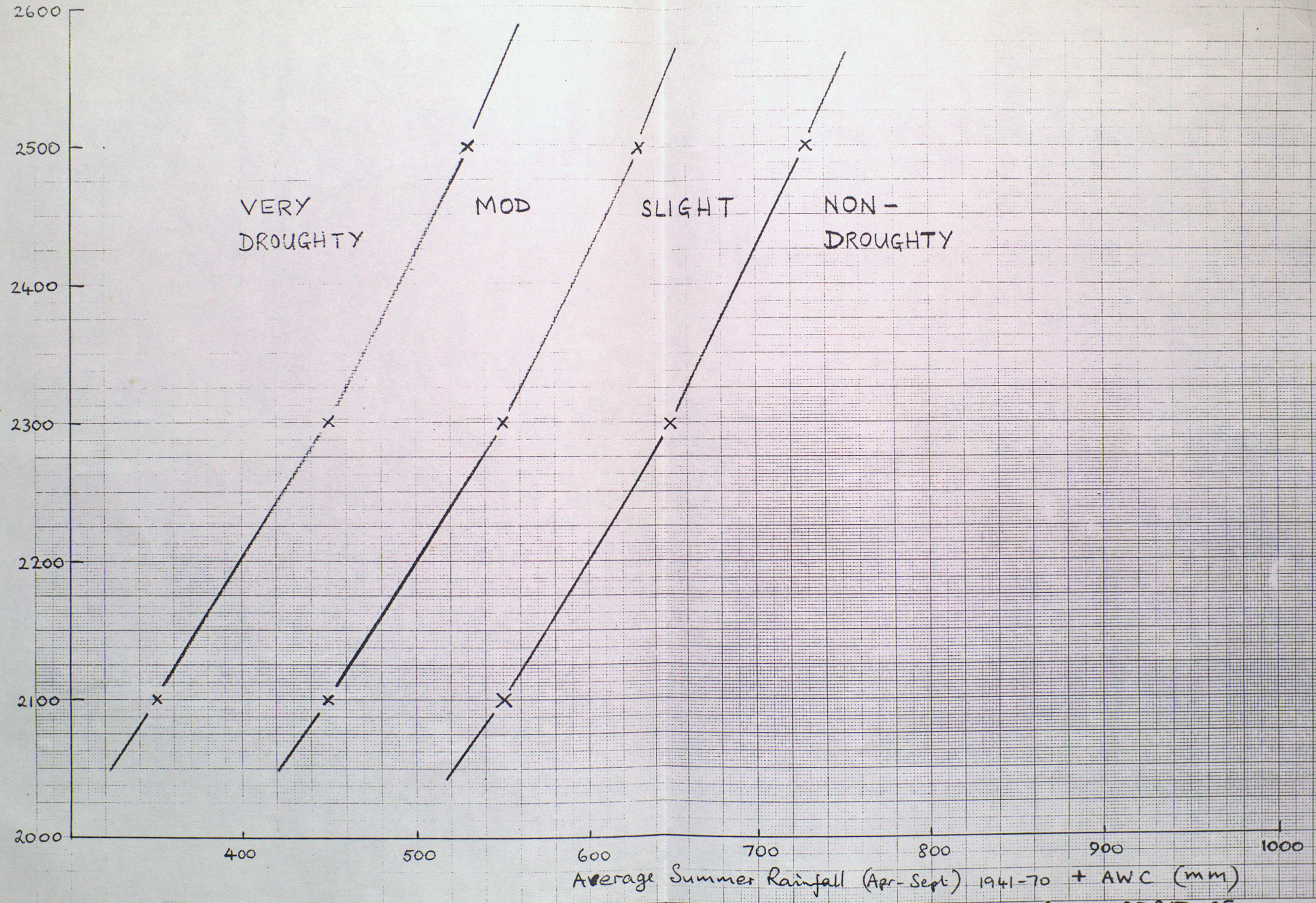


FIG 9 DROUGHTINESS INDEX BASED ON SUMMER RAINFALL + AWC AND SUMMER TEMPERATURE